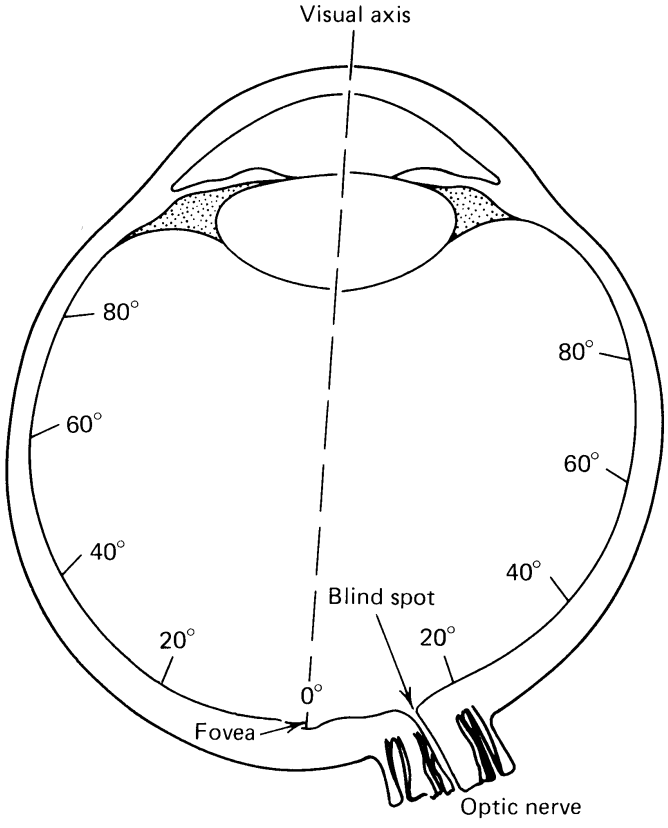
Overview

- **What are the strengths and limitations of humans that are most relevant to virtual environments and how we design for use?**
- **How do we evaluate systems based on user-centric analysis?**

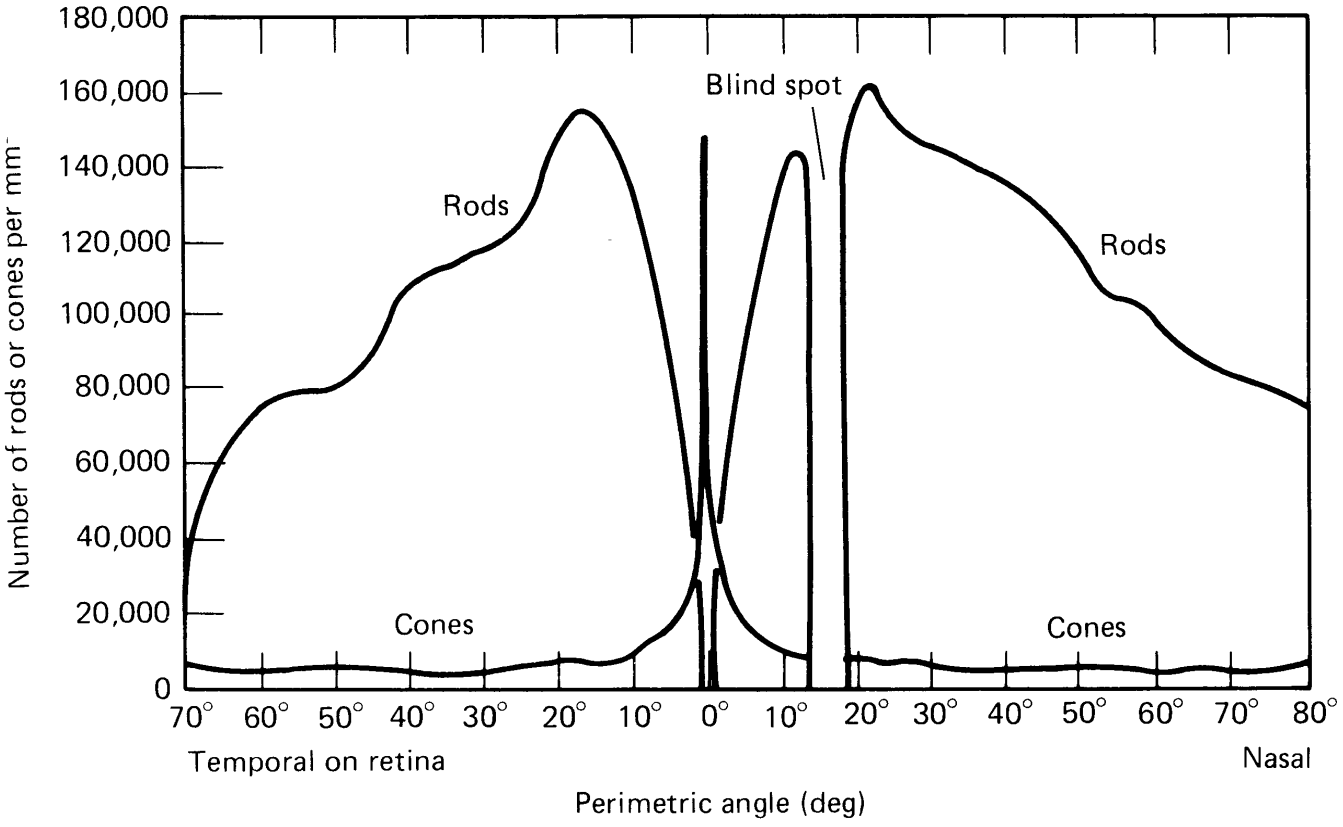
Perception

- **Vision**
- **Hearing**
- **Haptics/Touch**
- **Olfaction**

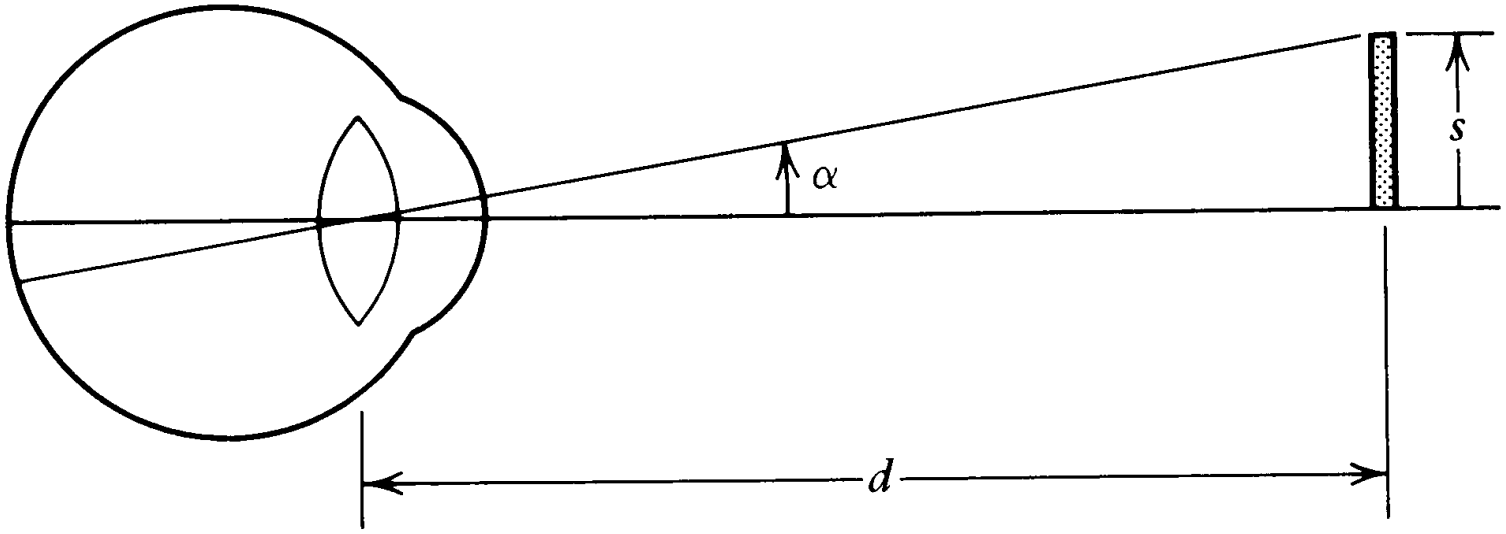
Vision


Visual axis
80°
80°
60°
60°
40°
40°
Blind spot
20°
20°
0°
Fovea
Optic nerve

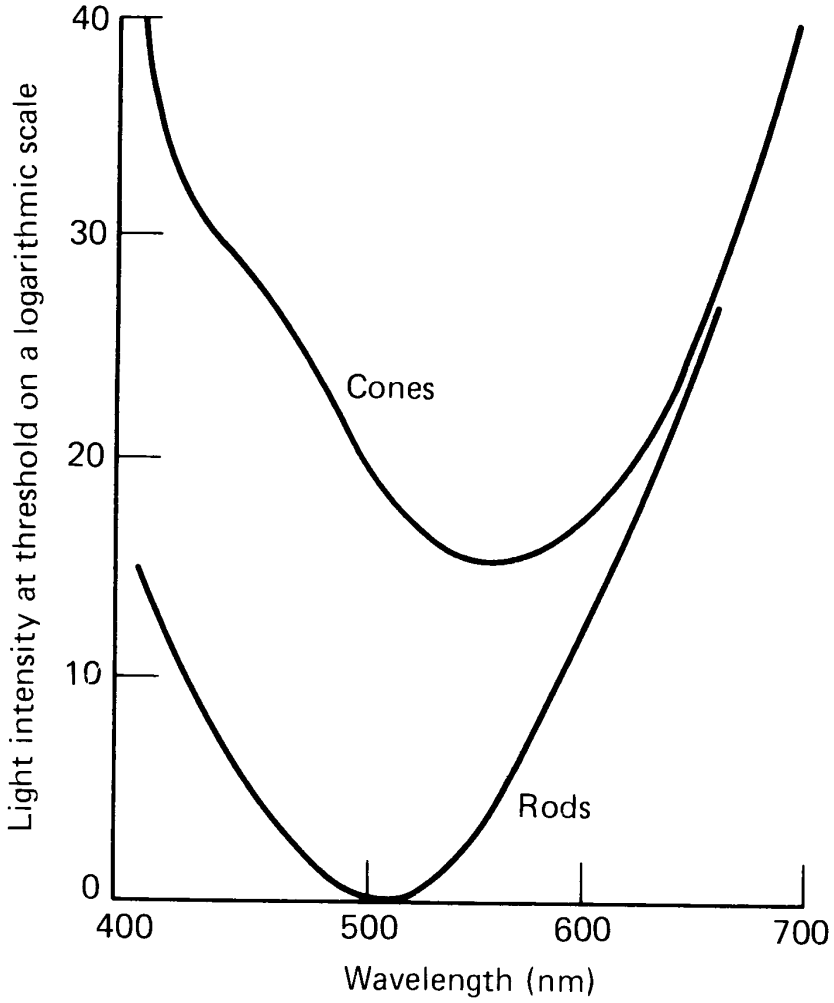
Rods and Cones



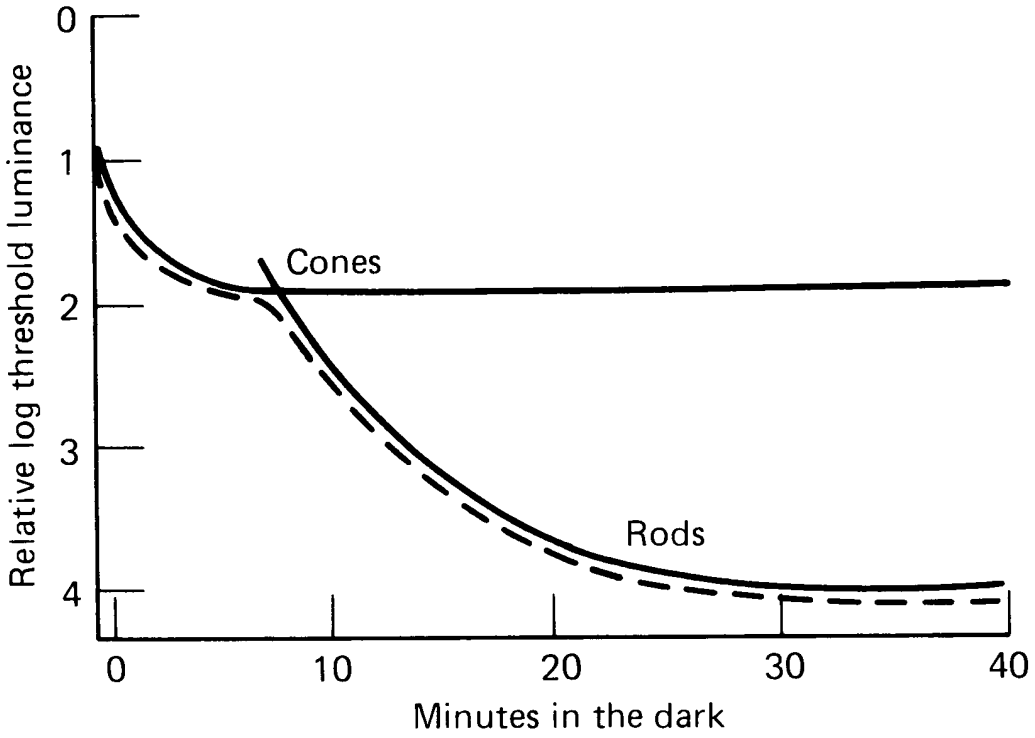
The Visual Angle



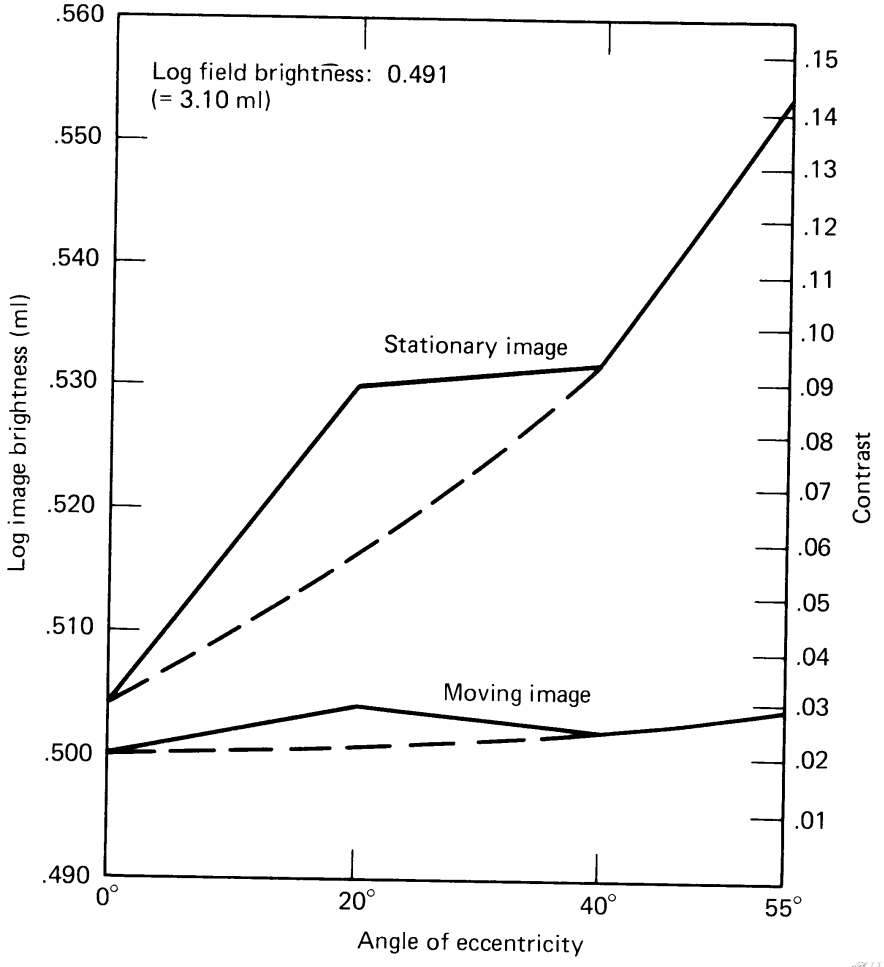
Intensity


40
30
20
10
0
Light intensity at threshold on a logarithmic scale
Cones
Rods
400
500
600
700
Wavelength (nm)

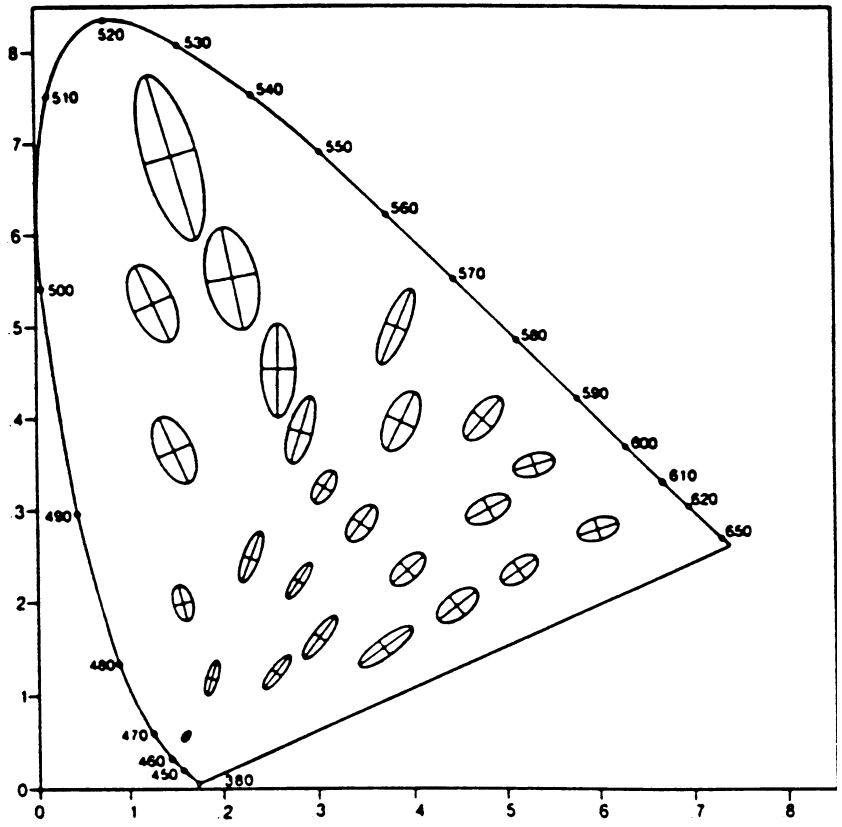
Dark Adaptation

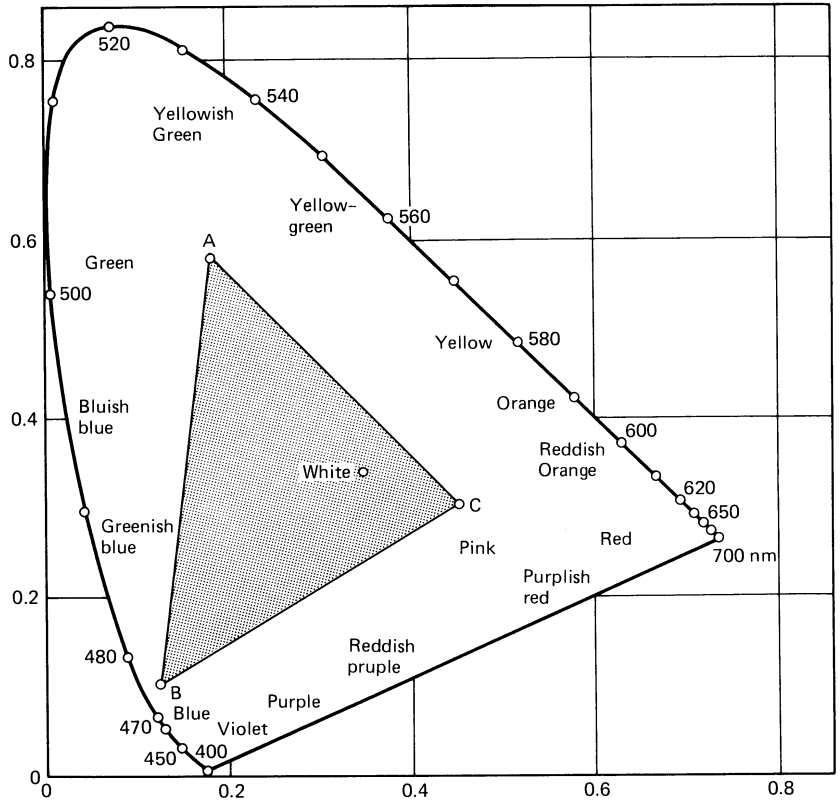


Contrast Sensitivity

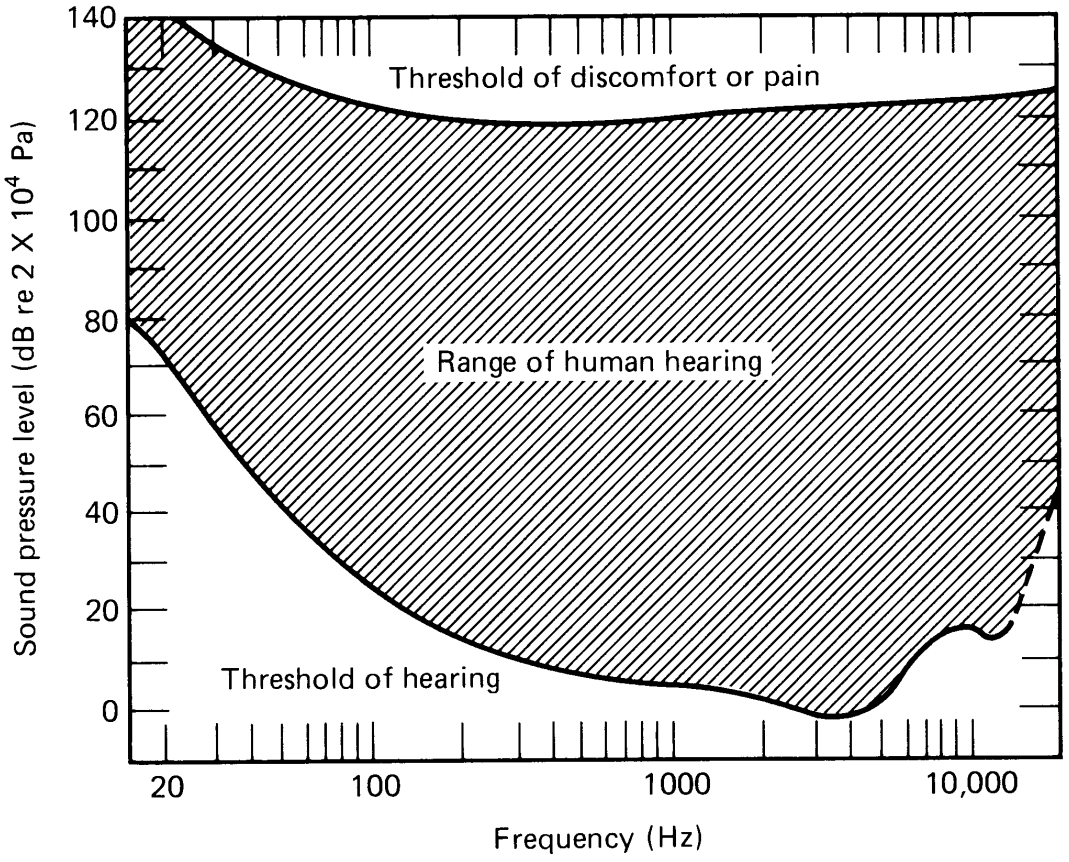


Color Perception

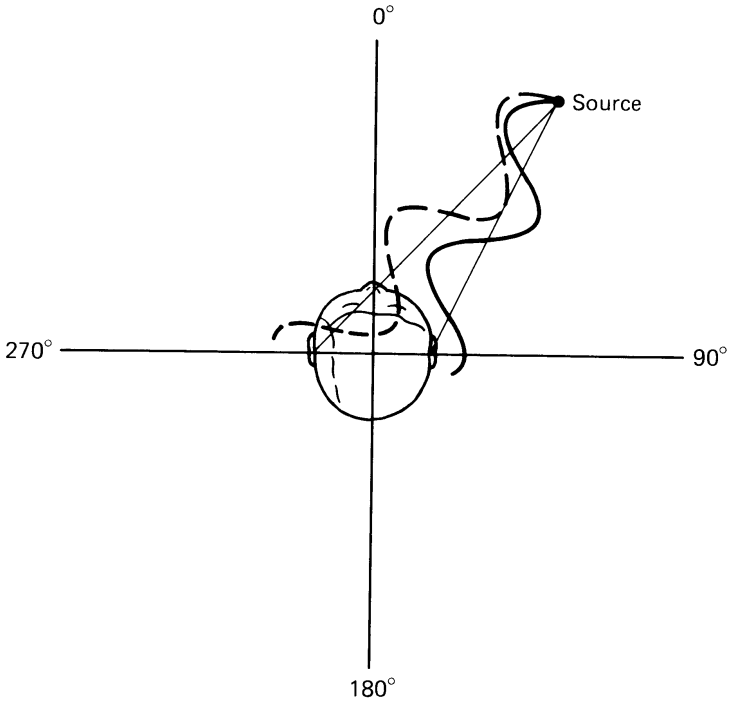




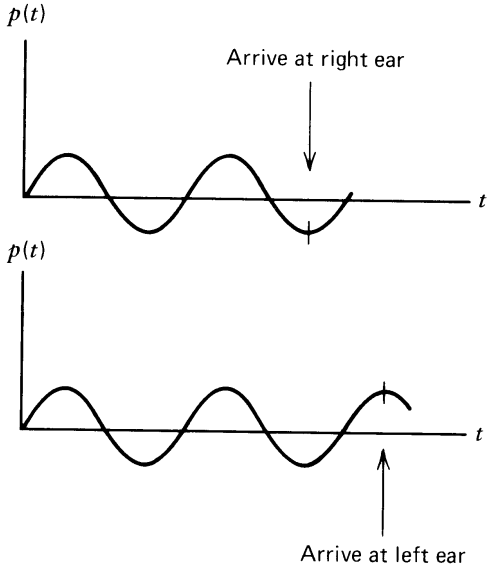
Aural Perception



Binaural Hearing

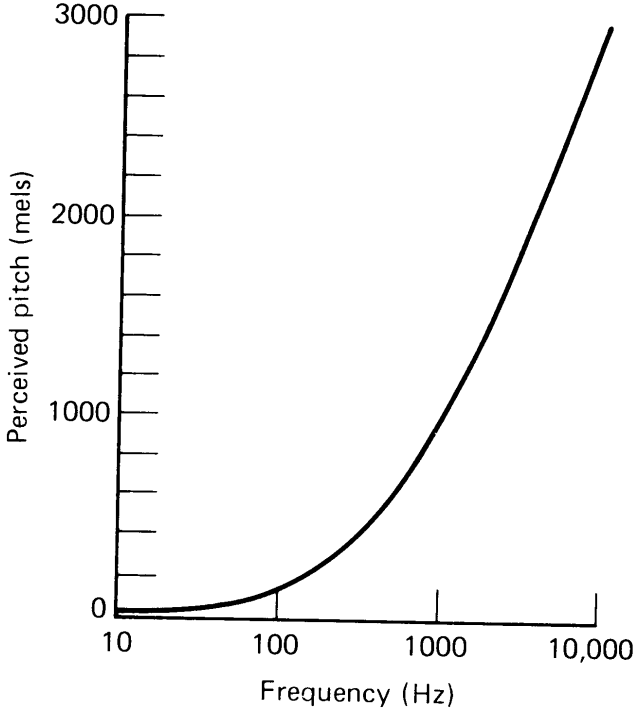


(a)



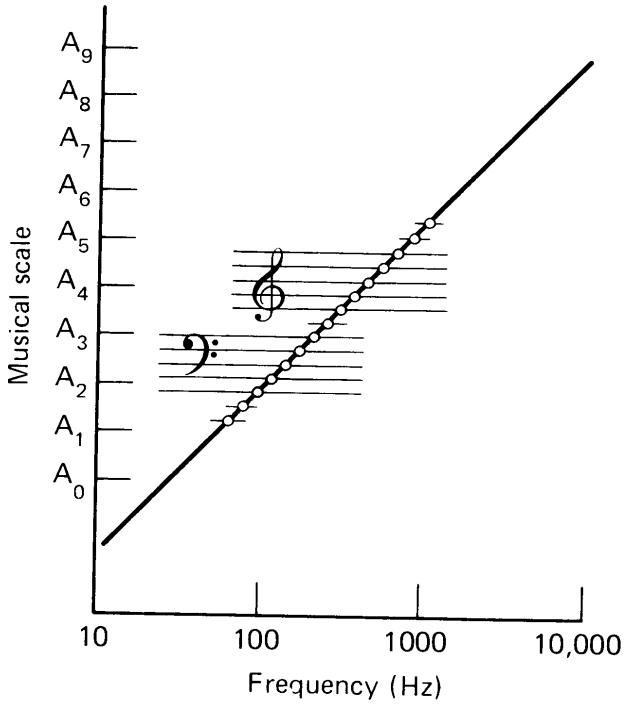
(b)

Pitch Perception



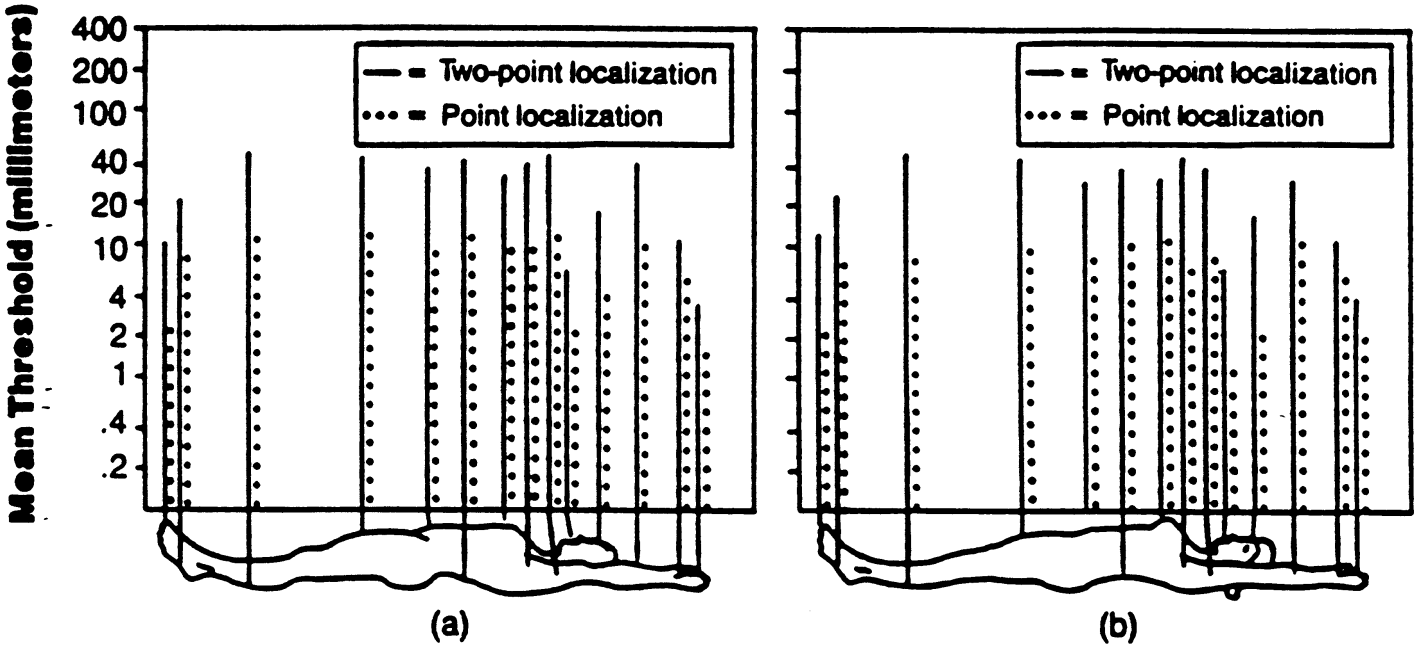
$$\text{mels} = 2410 \log (1.6 \times 10^{-3} f + 1)$$

(*a*)



(*b*)

Force Perception

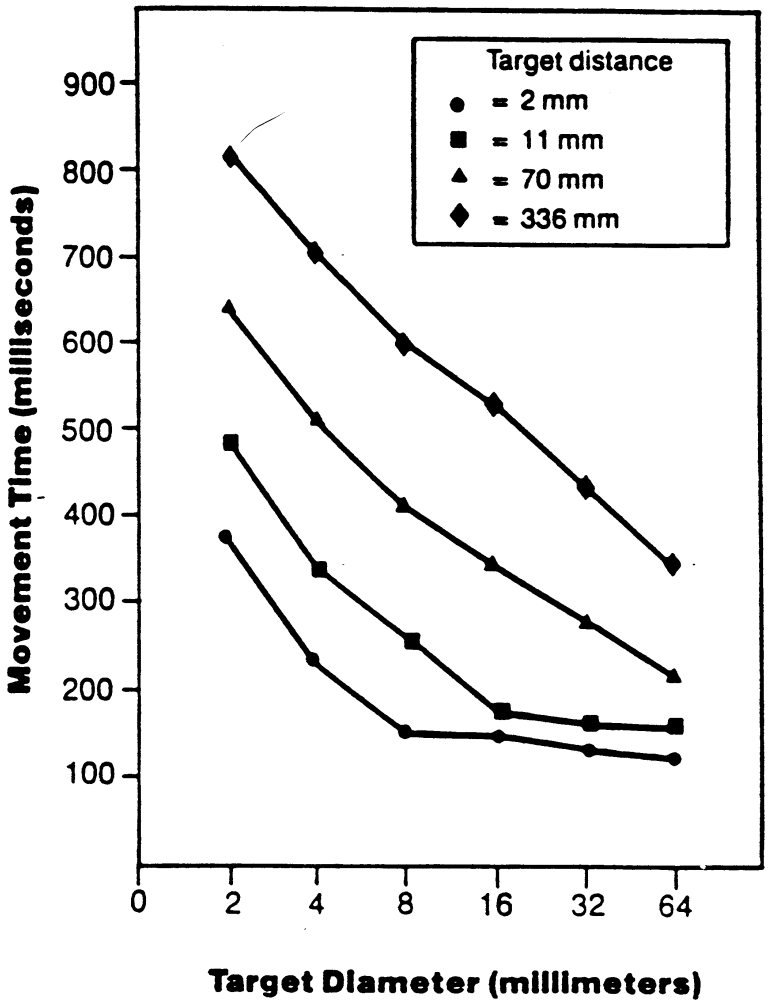


Males **Females**

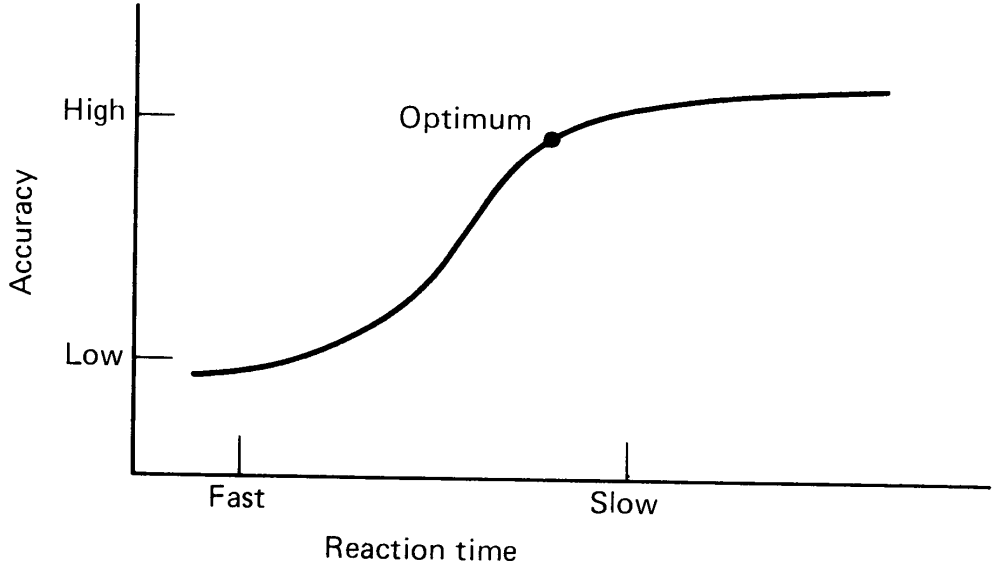
Motor Functions

- **Walking**
- **Pointing**
- **Manipulation**

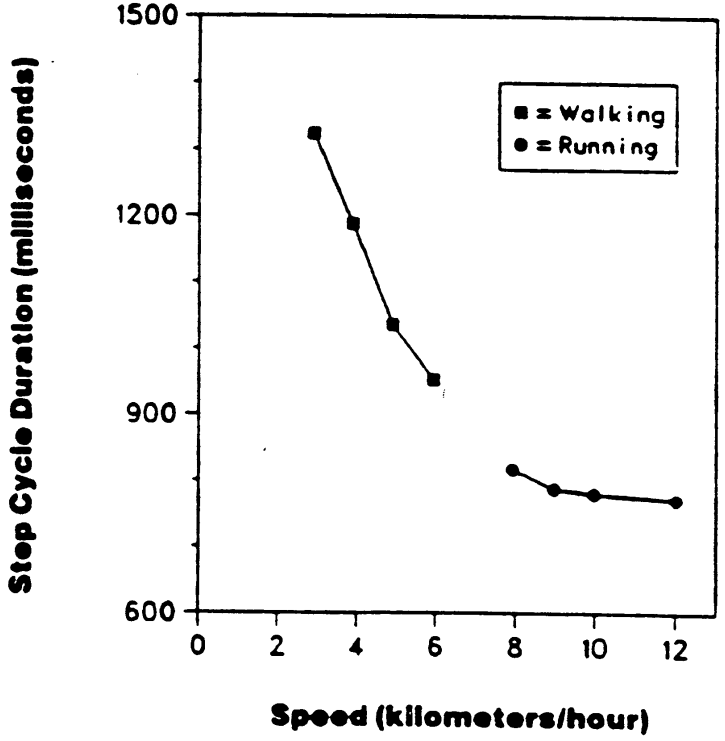
Pointing

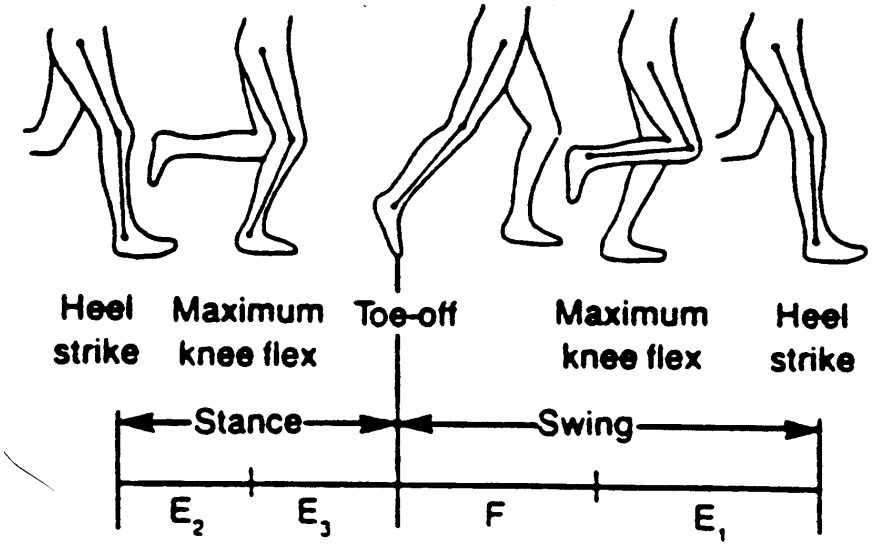

Target distance
= 2 mm
= 11 mm
= 70 mm
= 336 mm
Movement Time (milliseconds)
900
800
700
600
500
400
300
200
100
0
2
4
8
16
32
64
Target Diameter (millimeters)

Reaction Time



Walking


1500
1200
900
600
0
2
4
6
8
10
12
■ = Walking
● = Running
Step Cycle Duration (milliseconds)
Speed (kilometers/hour)


Heel strike
Maximum knee flex
Toe-off
Maximum knee flex
Heel strike
Stance
Swing
E2
E3
F
E1

Cognition

- **Memory**
- **Attention**
- **Planning**
- **Training/Learning**

Two-Crucial Bottlenecks

- **Navigation**
- **Cybersickness**

Navigation

Rarely the primary task

- **Consists of wayfinding and locomotion**
- **Navigation cues**
- **Organization of space, content structuring**
- **Path following**
- **Search behaviors**
- **Exploration, Different from searching?**

Cybersickness

- **Visual-vestibular mismatch**
- **Field of view issues**
- **Flicker effect**
- **Latency issues**
- **Proprioception**
- **Control in locomotion**

VE's for Training

- **Used very often as motivation for systems, but very little data supports this use**
- **Navigation training**
- **Surgical training**
- **Flight simulation**

User-Centric Evaluation

- **A system is not judged by its functionality but rather by its benefit to its users**

USER PERFORMANCE IS THE EVALUATION CRITERIA